Final report

iTRAK cattle retinal scanning accuracy field trial

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Abstract

Systems of permanent identification of cattle are challenging; tags are costly to purchase and insert, they can fail or be lost and offer no irrefutable proof of original identity (i.e. they are not tamper proof). Biometrics provides an opportunity to identify farm animals permanently and securely without requiring individual tags. Biometric recording of cattle has a number of challenges including the site for recording; the handling of animals to obtain biometric records; and the necessity to develop and maintain linked local and on-line reference databases of biometric data and images to ensure real-time animal recognition. Retinal patterns are unique to eyes and individuals, and like fingerprints provide a secure and whole-of-life system for identifying individuals. Retinal scanning is used in human security systems with success.

The iTRAK system is modifying the human / veterinary retinal scanning system to provide identification for animals. This project estimated the performance of iTRAK animal retinal recognition technology and explored the practicality of use of such a system on commercial farms. Approximately 40 cows from a commercial herd had individual retinal scans taken by multiple operators and using multiple iTRAK scanners over four visits separated by a minimum of two weeks over autumn and winter of 2022. Each cow was identified by NLIS ear tag and visual tag, and a baseline recording of the retina for the left and right eye was used as the reference image in the database. Subsequent visits and scans provide retinal images which were matched to the reference database to identify the individual cows.

Two subsequent visits failed to provide useable data for different reasons. The first revisit after the baseline recording was abandoned due to high ambient light conditions. The sunlight resulted in overly constricted pupils and no reliable retinal image was obtainable. All subsequent visits were conducted at night to avoid this problem, however the first night visit experienced a software failure; data was not written to file nor uploaded to the central database. The final night visit provided images from the 28 remaining cows. Two operators collected images using separate devices from each eye. This data was uploaded to the iTRAK server and analysed for accuracy in identifying each participant.

The algorithm matches pixels between the comparator and reference image library to find the best fit. If the best fit identified had 70% or more pixels matching between the images, a positive diagnosis (and animal identification) was reported. Pixel matches of less than 70% were reported as failed identifications. A total of 61 and 57 scans positively identified the correct cow for left and right retinal scans across the 74 images. The sensitivity of left eye scans was 82.4% (95 %CI = 71.5-90.0%; 61 of 74 scans identified the cow) and for the right eye scans was 75.7% (95% CI = 64.1-84.6%; 56 of 74 scans identified the cow). Applying a testing-in-parallel approach (i.e. at least one of the left or right scans confirming identification is required to identify the animal) the sensitivity was 93.2% (95% CI = 84.3-97.5%; 69 out of 74 scans identified the cow).

Several practical challenges were identified including the challenge of recording images in daylight; difficulty in operating the iTRAK scanner (see the viewfinder) whilst handling the cow; recording the optic disc region of the retina (due to the cows' slit-like pupil limiting full access to the whole retina) and occasional eye lesions (such as pinkeye and cataracts) preventing capture of images. Software refinements required include development of systems to rotate retinal scans to provide a matching north-south alignment to reference images, writing images to file and synchronising with the cloud database. The pattern matching algorithm likely also requires more development to ensure robustness in classification. The modest classification accuracy across fewer than 50 cows may be expected to decline as the reference database of potential matches increases. Ensuring the classification system does not overfit is an essential refinement for algorithm development.

Executive summary

Background

Systems of permanent identification of cattle are challenging; tags are costly to purchase and insert, they can fail or be lost and offer no irrefutable proof of original identity (i.e. they are not tamper proof). Biometrics provides an opportunity to identify farm animals permanently and securely without requiring individual tags. Commercial farms with high-value livestock and/or provenance stories require whole-of-life and tamper-proof animal identification. Biometric-based animal identification systems may provide this capacity to the market.

Objectives

- Determine accuracy of iTRAK retinal matching algorithm in correctly identifying individual cows under commercial environment.
- Explore practicality of retinal image scanning for animal identification on commercial farms.

Methodology

- A clinical trial where approximately 40 cows were identified and matched against visual ID and electronic ID (NLIS). A reference retinal image scans from left and right eyes was obtained. Subsequent visits recorded cow visual and NLIS tag ID and replicate retinal scans were obtained from left and right eyes.
- The classification algorithm accuracy was assessed using the proportion of subsequent images that were correctly matched to the reference image for each cow and for each eye.

Results/key findings

The current variant of the iTRAK classification algorithm had modest sensitivity at eye level. The sensitivity of left eye scans was 82.4% (95 %CI = 71.5-90.0%; 61 of 74 scans identified the cow) and for the right eye scans was 75.7% (95% CI = 64.1-84.6%; 56 of 74 scans identified the cow).

Applying a testing-in-parallel approach (i.e. at least one of the left or right scans confirming identification is required to identify the animal) the sensitivity was 93.2% (95% CI = 84.3-97.5%; 69 out of 74 scans identified the cow).

There are operational challenges to use of this technology on farm animals. Ambient light causes excessive pupillary constriction to allow suitable retinal image capture using the iTRAK camera under typical daylight conditions. The current hardware is difficult to use whilst handling the cows' head (hard to see the viewfinder) and the presence of eye disease (cataracts and pink eye) can prevent suitable image capture from individual cows.

The algorithm may be prone to overfitting. This can be improved by construction of a much larger trial set of data – obtained from multiple animals, multiple farms and multiple operators such that a training and testing dataset and cross-validation techniques can refine the algorithm.

Benefits to industry

Biometric-based animal identification provides many advantages over existing tag-base systems including cost, reliability, robustness and tamper resistance. However, there are challenges to recording biometric data in large farm animals and logistical restrictions may exists - such as the necessity to access on-line databases when assuring the provenance of an individual animal.

Future research and recommendations

Refinements to the algorithm are essential. More training data is essential to allow the algorithm to improve in accuracy and robustness. This is a typical journey for artificial intelligence-based systems, and not peculiar to iTRAK.

Adjustments to hardware and software and more robust data transfer systems may be required to provide commercial usefulness for the system. Cameras that can capture the whole of the retina through slit-like pupils and which can operate in daylight conditions are also recommended.

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1. Background

Australian agriculture, through the National Farmers' Federation, has laid down a bold vision for the industry – to exceed $100 billion in farm gate output by 2030 (www.nff.org.au/policies/roadmap)

However, it has also identified several challenges in meeting this goal, including:

- Consumer's diets are changing, and production must monitor these changes and adjust accordingly.
- Customers are increasingly focused on where their food and fibre come from, including consideration of issues such as animal welfare, sustainability, safety, and nutrition.
- In addition to productivity, producers must increasingly consider the ethical, environmental, and nutritional requirements of consumers.
- 'Brand Australia' is respected as a global leader in issues such as sustainability, food safety and animal welfare, but ongoing realignment with customer expectations, together with ongoing validation, are required.
- Ongoing effort is required to maintain and enhance the perception of Australia being a trusted source of food and fibre. The risks of food fraud must be addressed through objective validation through the whole supply chain.
- Australia's traceability systems are world-class and have served the Australian industry well to date. However, ongoing assessment of opportunities for improvement are required to add efficiencies and ensure the industry continues to lead in this area.
- Data needs to flow up and down the supply chain to support transitioning from a 'Commodity disposal model' to a 'value creation model'.
- Infrastructure must continue to evolve, improving the path from farm to market.

Against this backdrop of increasing challenges to agriculture, a fundamental requirement to meet these future challenges is to have an effective livestock identification and traceability system. This system is essential to:

- Demonstrate the health, provenance, sustainability and ethical production of meat and livestock.
- Deliver safe meat and meat products to consumers.
- Underpin market access and provide transparency through supply chains.
- Support improved productivity and increased efficiencies throughout the supply chain.
- Demonstrate production and processing meets environmental requirements and expectations.
- Deliver to consumer expectations, increasing trust in agricultural commodities.
- Mitigate the risks of food fraud and stock theft.
- Meet regulatory requirements.
- Deliver biosecurity and respond to biosecurity threats.

Australia is recognised as a world leader in livestock identification and traceability. Systems like Australia's National Livestock Identification System (NLIS) is recognised and respected around the globe as 'best practice'.

However, NLIS relies on electronic ear tags that have been in place for over 30 years. While they have served the industry well to meet the challenges identified above, the system is not perfect and there may now be better technology options available. Issues such as tag losses / removal make it impossible to maintain the identity of individual animals.

For example, producers have reported up to 100% loss of tags over eight years (the commercial life cycle of a cow). This is compounded by difficulties in capturing data to understand the extent of the problem (www.beefcentral.com/news/tag-retention-nlis-tag-losses-still-frustrating-producers).

Current buoyant market conditions have contributed to an increase in stock theft, as is regularly reported in the press. However, current identification systems make it very difficult to prove ownership – especially once a tag is removed.

The exponential advances in agricultural technologies (Agtech) in recent times can contribute to an identification and traceability solution that addresses current weaknesses. However, the rapid growth in Agtech has created new challenges.

A recent report from Meat and Livestock Australia (MLA), Barriers to Adoption and Extraction of Value from Agtech in the Australian Livestock Industry (V.RDA.2008, Feb. 2021) identified seven thematic areas that affect the adoption of Agtech. These are:

- Value proposition – Agtech needs a compelling value proposition – it needs to address and effectively solve a customer's problem.
- Data issues – covers the critical areas of data collection and storage, ownership (intellectual property rights), privacy and data quality (standard language definitions, completeness, accessibility).
- Infrastructure – beyond the actual Agtech itself, digital connectivity is often a challenge in rural areas where it is often unavailable, slow, unreliable, and/or expensive.
- Policy and regulation – include intellectual property protection and safety standards for Agtech, addressing not just constraints imposed by government, but also regulations to ensure proper use of the technology.
- Skills – include those needed by producers (and other actors along the supply chain) to understand and operate the technology, and/or local access to technological expertise and associated support services.
- Social – to gain adoption, trust needs to be earned between the Agtech provider and the producer. This is particularly relevant where technology avoidance is an issue.
- Technology – ease of adoption, interoperability with other Agtech, useability, and the need for further supporting R&D can be barriers to adoption.

Any new Agtech must consider and address each of these themes as part of their development.

iTRAK recognises the need for an improved identification and traceability system, the challenges in developing new Agtech and the opportunities offered through the innovative application of technology to address modern identification and traceability needs. As a result, iTRAK is applying its extensive knowledge and experience in agriculture to identify how digital technologies can be applied to help prepare the industry to meet future identification and traceability challenges. It is well understood that current systems rely on old technology, including externally applied devices that can fall out, be removed or defaced, or fail. They are largely reliant on a paper trail to confirm movement history and are the same cost per head, regardless of end use, level of risk or value of animal.

The ultimate target of this work is the livestock industries although, as development progresses, the target markets will become more defined. It is anticipated that subsets of the industries will be initial targets.

An initial step of the project will be to determine the individual data to be captured by the project and how it will be recorded. In addition to the actual retinal scans, this will include issues such as time to scan, data files sizes and qualitative issues such as ease of scanning, barriers to scanning, etc.

Once the trial site is identified, training will be organised prior to the first scan to ensure all parties engaged in the process understand their roles and there are clearly documented processes to be followed.

The retinal scan will be correlated with each animal's NLIS device, and visual tags.

The project will:

- Demonstrate that individual cattle can be accurately identified using the Scanner.
- Confirm that the Scanner will accurately identify cattle repeatably.

This final report will:

- Identify any initial challenges to using the Scanner for identification purposes, particularly in a commercial environment.
- Propose an adoption and commercialisation pathway for the technology.
- Propose additional research if required.

This is an initial project, primarily to demonstrate 'proof-of-concept'. It will also provide meaningful input into the next steps for the technology.

2. Objectives

The Australian red meat industry has a global reputation as a supplier of clean, safe and natural product, underpinned by its disease-free status and advanced food safety and integrity systems. To maintain our competitive advantage, the red meat industry must pursue and invest in new technologies and approaches to integrity that address current and future customer requirements, maximise value and improve uptake across the industry. Integrity Systems Company (an MLA subsidiary) (ISC) has a vision of a fully automated supply chain, and this project aligns with its strategic target of real-time traceability.

The aim of the project is to conduct a proof-of-concept pilot using retinal scanning for individual animal identification, which has been developed for the security industry and is now being made available for animal applications. This is an initial trial to demonstrate that the technology can be used on cattle, as a first step in assessing its application to the livestock sector, identify any challenges to its use and to identify next steps in commercialising it in the livestock industries.

Using computers to monitor and record animal movements could greatly reduce human labour and costs associated with NLIS compliance.

The objectives of this project are:

By the conclusion of the project the following will have been achieved:

1. Group of 40 cattle secured for use in the trial including a range of ages and sexes.
2. Both retinas of each animal scanned and correlating with an NLIS RFID device.
3. Repeat the scanning of both retinas of each animal three times, with each reading at least two weeks apart.
4. Review the individual data and determine the actual level of accuracy and repeatability of the Scanner.

3. Methodology

A field trial of the technology was undertaken on a commercial dairy farm in Gippsland. A dairy farm was chosen due to geographic location, access to technical resources and that dairy cattle would be more suited to trial work than beef cattle as they are frequently handled.

3.1 Ethics Approval

Before commencing the trial, Ethics Approval (EI) was sought from the Victorian Government's Department of Jobs, Precincts and Regions (department). Given the type of cattle being used and the lack of impact on the animals from the proposed procedures, EI was anticipated to be a simple process.

Discussions commenced with the Department in October 2020, with an application being lodged on 23 February 2021. Approval was finally received on 23 February 2022. This resulted in a 12-month delay to the program and a resulting contract variation.

3.2 Hardware

iTRAK is a joint venture company formed by FoodFibreTrace Pty Ltd (IP holders of traceability systems) and Optibrand LLc, (Patent holders for retinal scanning technology for eye health & security purposes www.optibrand.com).

Even though their current 'ClearView2' scanner has primarily been designed for veterinary and human health purposes, this trial used the current 'ClearView2' scanner for this trial (Image 1).

Image 1 Optibrand Scanner

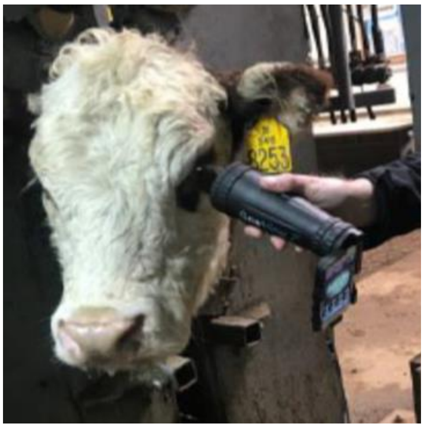


Image 1 shows that the scanner consists of a magnifier that is connected to an Apple iPod®. The lens of the magnifier is held approximately 10cm from the eye. The iPod shines a light through the magnifier which (once properly aligned) passes into the eye and is reflected off the retina, projecting an image back to the iPod. The proprietary software in the iPod recognises a retina and automatically captures images of it. These are subsequently assessed by the operator to manually choose the best image.

3.3 Software

This trial used the Optibrand software to capture the images. iTRAK has developed its own software for the iPod to take the images from the Optibrand software and deposit them, together with the metadata, in a cloud-based database. As well as storing images (image library), the iTRAK software can compare an image to all images in the image library to identify the closest match. Using a pixel count, it produces a percentage accuracy with the closest match. An arbitrary benchmark of 70% correlation has been set as the pass/fail point. That is, any match greater than 70% is deemed a 'pass' and any match less than 70% is deemed a 'fail'.

3.4 Study design

A cattle farm with individual animal electronic and visual identification were the primary characteristics sought for selection. As well as cows being double identified, additional criteria included being likely to remain within the herd for the foreseeable future and amenable to handling in standard farm infrastructure (i.e. yards and crush).

Once a preferred property was selected, cows were individually processed through the farm crush with the animal's head restricted in the head bail of the crush. Electronic ID was read by NLIS wand and visual tag recorded. The first visit recorded the left and right retina of each trial cow against their ID and was used as the reference recording (reference library).

Replicate reads were undertaken a minimum of two weeks apart where at least one retinal scan was taken of both the left and right eye using the ITRAK scanner and with at least one operator.

The sensitivity and specificity and confidence interval of the estimates of cow identification on subsequent reads were calculated and reported.

The practicality of recording retinal scans was assessed across the course of the trial and recommendations for use reported.

4. Results

4.1 Farm and cows

A Victorian dairy farm (Nambrok) meeting the selection criteria was identified and forty-one mixed-breed (but predominately Friesian) cows meeting the selection criteria were recruited. Farm auto-draft software was programmed to draft cows when field visits were planned.

Table 1 Trial cows

No	Herd Rec ID	Cow HRID*	Cow NLIS ID	Breed	Lactating	Temperament	Birth Date	Age	Last Calving
1	815542	952	964 001007398769	FFFF	1	1	13/8/2012	10	30/8/2021
2	815542	1376	982 123526906325	FFFF	1	1	22/8/2016	6	26/8/2021
3	815542	1387	982 123526905940	FFFF	1	1	31/8/2016	6	8/9/2021
4	815542	1396	982 123526905621	FFFF	1	1	9/9/2016	6	8/9/2021
5	815542	1441	982 123537207758	FFFF	1	1	22/3/2017	5	7/9/2021
6	815542	1453	982 123767295726	FFFF	1	1	26/7/2017	5	26/9/2021
7	815542	1482	964 001008267836	FFFF	1	1	16/8/2017	5	12/9/2021
8	815542	1512	982 123537207932	FFFF	1	1	18/9/2017	5	23/10/2021
9	815542	1526	982 123547223205	FFFF	1	1	11/3/2018	4	20/8/2021

No	Herd Rec ID	Cow HRID*	Cow NLIS ID	Breed	Lactating	Temperament	Birth Date	Age	Last Calving
10	815542	1529	982 123547223204	FFFF	1	1	13/3/2018	4	12/10/2021
11	815542	1587	982 123724656822	FFFF	1	NA	17/8/2018	4	26/9/2021
12	815542	1600	982 123719131922	FFFF	1	NA	4/9/2018	4	13/9/2021
13	815542	1623	982 123723194304	FFFF	1	NA	30/9/2018	4	21/8/2021
14	815542	1696	964 001008318026	FFFF	1	1	27/7/2019	3	29/9/2021
15	815542	1721	964 001008317843	FFFF	1	1	18/8/2019	3	26/9/2021
16	815542	1726	964 001008318047	FFFF	1	1	19/8/2019	3	1/10/2021
17	815542	1911	982 123737688276	FFFF	1	1	28/5/2019	3	30/7/2021
18	815542	2477	982 123723194245	FFFF	1	1	23/8/2017	5	20/8/2021
19	815542	4140	964 001030419565	FFNF	1	1	3/4/2016	6	24/9/2021
20	815542	4143	982 123516877780	FFJF	1	1	5/4/2016	6	4/10/2021
21	815542	4193	964 001007398225	FFFF	1	1	31/7/2016	6	27/9/2021
22	815542	4256	982 123526906256	FFJF	1	1	25/7/2016	6	17/9/2021
23	815542	4274	982 123526906356	FFJF	1	1	31/7/2016	6	30/9/2021
24	815542	4333	964 001008268123	FFFF	1	1	29/5/2014	8	27/9/2021
25	815542	4423	982 123526905572	FFFF	1	1	19/9/2016	6	2/10/2021
26	815542	4433	982 123526905543	FFFF	1	1	23/9/2016	6	26/10/2021
27	815542	4540	982 123526905603	FFFF	1	1	30/8/2016	6	7/10/2021
28	815542	4592	982 123526906119	FFFF	1	1	6/10/2016	6	26/9/2021
29	815542	4798	982 123537207561	FFJF	1	1	17/8/2017	5	12/10/2021
30	815542	4865	982 123547222680	JJFX	1	1	5/10/2017	5	20/8/2021
31	815542	5264	982 123723194230	FFFF	1	1	18/8/2018	4	21/10/2021
32	815542	5352	982 123547223140	FFFN	1	1	27/8/2018	4	23/9/2021
33	815542	5430	982 123719131912	JJFF	1	1	4/9/2018	4	16/8/2021
34	815542	5464	982 123723194365	JJFN	1	1	20/9/2018	4	29/9/2021
35	815542	5527	982 123723194260	FFFF	1	NA	23/3/2019	3	28/9/2021
36	815542	5589	964 001030419862	FFFJ	1	1	10/8/2019	3	26/9/2021
37	815542	5625	964 001008319191	FFFF	1	1	29/7/2019	3	17/9/2021
38	815542	5699	964 001030418717	FFLJ	1	1	18/8/2019	3	5/9/2021

No	Herd Rec ID	Cow HRID*	Cow NLIS ID	Breed	Lactating	Temperament	Birth Date	Age	Last Calving
39	815542	5733	964 001008318747	FFFF	1	1	22/8/2019	3	2/8/2021
40	815542	5802	964 001008318790	JJNF	1	1	8/9/2019	3	14/9/2021
41	815542	5854	964 001008319267	JJFN	1	NA	30/9/2019	3	11/8/2021

*HRID = Herd record Identification

4.2 Farm visits

Farm visits occurred on 7th April 2022, 14th April 2022, 28th April 2022, 15 June 2022. Data was recorded using two iTRAK retinal scanners and using two operators (PL and RWS).

Visit 1 (baseline) on the 7th April 2022 occurred in the afternoon of an overcast day. The visit on 14th April 2022 also occurred mid-afternoon and was in bright sunlight. This data session was subsequently abandoned as the ambient light resulted in excessive pupillary constriction to obtain retinal scans of suitable quality.

The last two visits (28 April 2022 and 15 June 2022) were timed to occur at night — beginning from 5PM — to ensure cows has suitably dilated pupils.

4.3 Data

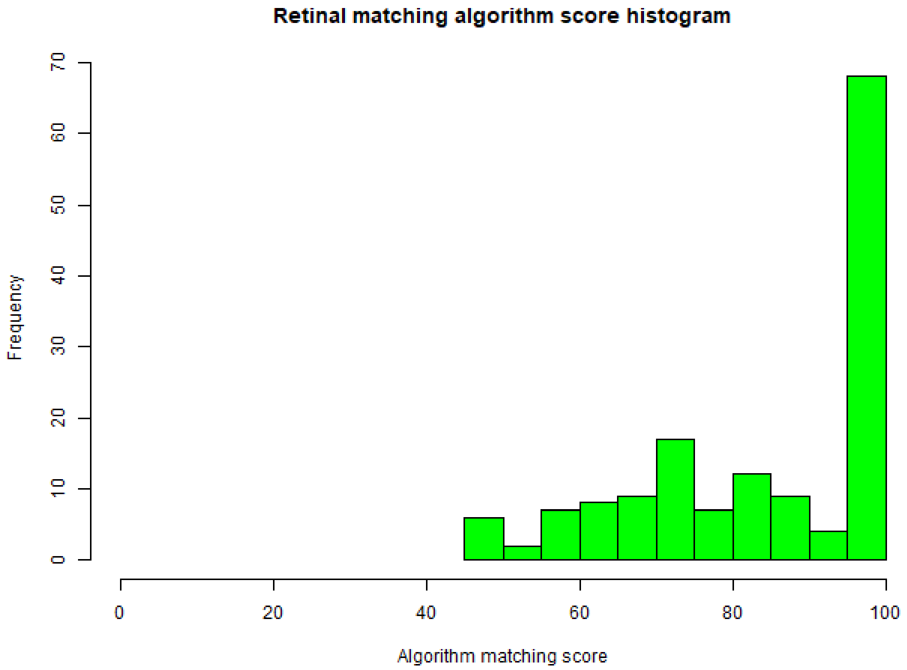
The data from visit three (28 April 2022) failed to upload to the server and no copy was kept locally on the device to file. Subsequently, all data was lost. A revisit was required to collect comparator data. This visit (no. 4; 15th June) was successful; data was recorded from two operators using two devices, uploaded to the server and saved to file. However, only 28 of the original 40 cows were available by the 15th June; missing cows were either culled or dried off and removed from the farm as part of their dairy production cycle. This highlights the need to have shorter periods between initial and subsequent readings to ensure availability of animals, as well as using larger sample sizes.

4.4 Analysis

The proprietary algorithm was used to match subsequent retinal scans against the reference library of images (scans obtained from the first recording for each cow). A matching score was provided for each cow with a cut-point for determining match fit set at 70.0

The distribution of eye matching scores is presented at Figure 1, below.

Figure 1 Matching Scores of Subsequent Images Compared to Reference Library



The scans of the left eye results were 61 confirmed matches and 13 unmatched observations and for the right eye were 57 confirmed matches with 18 unmatched observations. The combined performance for individual cows (left and right eye) are presented in Figure 2.

Figure 2 Comparison of Matched and Unmatched Observations for Left and Right Eyes

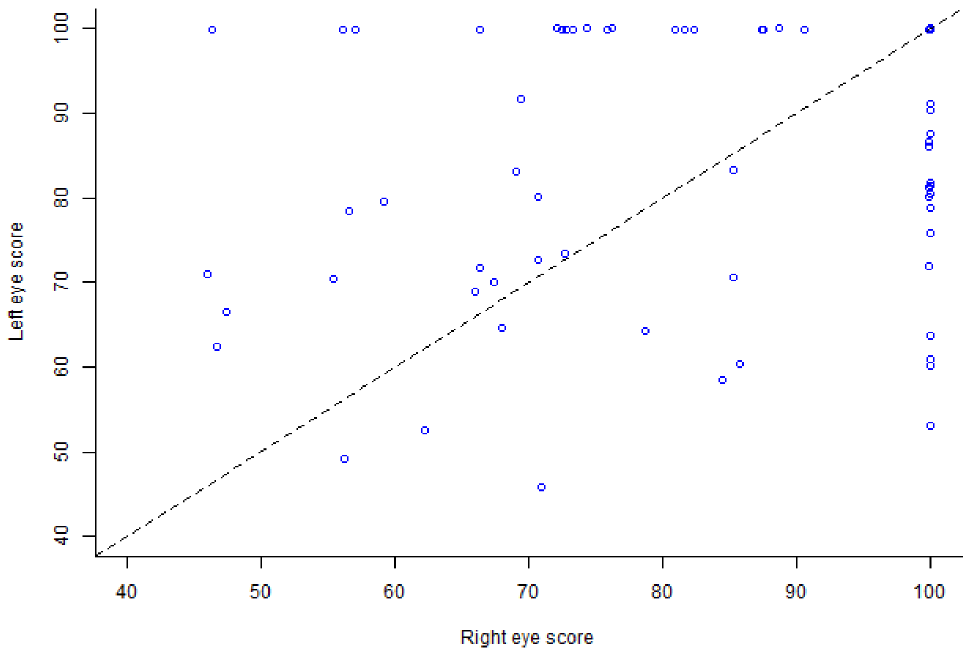
		Right eye		
		Unmatched	Matched	Total
Left eye	Unmatched	5	8	13
	Matched	13	48	61
	Total	18	56	74

The sensitivity of left eye scans was 82.4% (95 %CI = 71.5-90.0%; 61 of 74 scans identified the cow) and for the right eye scans was 75.7% (95% CI = 64.1-84.6%; 56 of 74 scans identified the cow).

Applying a testing-in-parallel approach (i.e. at least one of the left or right scans confirming identification is required to identify the animal) the sensitivity was 93.2% (95% CI = 84.3-97.5%; 69 out of 74 scans identified the cow).

There was no evidence of correlation between left and right eye matching results (Chi-squared = 0.907, df = 1, p = 0.34). This suggests there are no obvious systemic (cow-level) factors that contribute to accuracy (see Figure 2).

Figure 2 Left versus Right Eye Matching Score Scatterplot



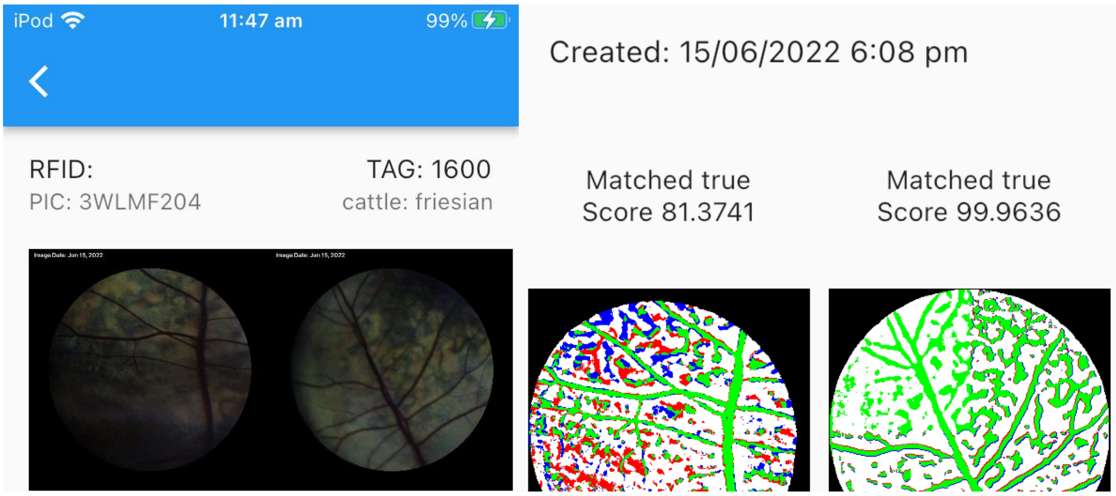
5. Discussion

The ITRAK algorithm demonstrated modest accuracy at eye level but high accuracy at cow level (when both eyes were scanned). Whilst the current level of accuracy is insufficient for commercial application of animal identification and assurance, improvements are possible to algorithm performance. More training data will be required to provide a suitably sized learning dataset for algorithm refinement.

Training data from multiple cattle, and multiple observations and from more than one operator will be necessary to ensure that the detection algorithm is suitable sensitive and robust for use. One aspect of algorithm development is avoiding over-fitting, and large and diverse training and (different) testing data sets are essential. This requires, time, resources and diverse expertise to undertake; but is essential for providing a robust, working and trustworthy commercial system. One specific aspect of the algorithm will be to test images in various states of rotation against the reference images. As can be seen in Figure 3, there is a main vein that runs through the retina. Ideally, this vein should run vertically through the image. However, cows, unlike humans, are unlikely to provide perfect ‘north-south’ oriented images in each recording so the algorithm for animal use must be able to rotate images to find optimal fit to reference. The current iTRAK software does not do this.

This trial examined 41 cows. This means every test image was tested against a reference database of 41 retinas (for each eye). The impact of a larger reference library (i.e. more cows) is unknown, but a reduction in matching accuracy is likely – the more possible matches there are for a scan the more likely is a false match. This effect will need to be examined with a larger dataset of images.

Figure 3 Output Screen from iTRAK Software



The slit-like pupil of the cow enables images of half retinas to be obtained depending upon how the camera is pointing relative to the centre of the eye. Numerous retinal scans were obtained that included or excluded the optic disc region and associated veins. There is a risk that a reference or comparator image from a cow may not include the same sections of the retina and thereby prevent retinal matching. Not only is this challenging, but also requires a high level of skill by the operator to align the scanner correctly.

Obtaining retinal images can be physically challenging. The camera must be positioned within 10 cm of the eye and held pointing towards the optic disc area of the eye. This can be a threat to the operator and any associated cow handler as a cows' head is potentially a large club that can strike hands, faces, heads etc of operators that are within the range of movement. The current technology requires operators to position themselves within this range of movement and so there are potential work, health and safety implications from collecting images.

The current design of the retinal scanner makes it difficult to capture retinal images. The scanner is designed for use as an ophthalmological tool to take retinal scans of pets. As identified above, trying to capture an image of a large, potentially dangerous animal in a commercial environment is challenging. The design of the scanner is such that an operator needs to have the iPod in their line-of-sight to see when the scanner is properly aligned with the retina. However, the operator must also be looking at the animal's eye at the same time to see where the light beam generated by the iPod is entering the eye of the animal as a guide to help locate the retina, refer Figure 4. As can be seen from Figure 4, if an operator has the iPod central in their field of vision, the eye of the animal cannot be seen.

Noting that the scanner is designed for use on pets and humans, any future scanner must be designed to handle the rigours of operating in stockyards, as well as being able to view the iPod screen and the eye of the animal simultaneously.

The effects of ambient light are significant. Under normal bright daylight conditions, the pupillary light reflex maintains a narrow pupil by operating the iris. The current iTRAK scanner struggles to obtain full retinal scans of cows when their pupils are (normally) restricted in size due to ambient light – for some cows the time required to collect a suitable retinal image can be many minutes and for others no suitable image can be obtained. This has implications for commercial use of the technology where the operation under typical daylight conditions – especially in summer – may not be possible.

Figure 4 Scanning the Retina

Finally, one cow for testing was identified with active pinkeye and the extent and degree of cloudiness of the cornea prevented an image from being taken, however one other cow had old corneal scars from a previous pinkeye infection on one eye and this eye provided suitable images for analysis. At least one cow had cloudy lenses (developing cataracts), which proved difficult to obtain a retinal scan (taking more time than for other cows).

Some of these problems will reduce as technology and algorithms improve but some also are unlikely to be eliminated – such as the ambient light, cow eye injury and operator safety problems, and these therefore may impact commercial considerations

6. Conclusion

6.1 Accuracy of retinal scan recognition

The current technology has modest accuracy for single-eye scan recognition, but the accuracy improves when both eyes are used to confirm a cows' identity. The current algorithm has not evolved to commercial performance. More development is necessary.

6.2 Practical use comments

Obtaining a retinal scan on cows with constricted pupils is challenging and time consuming. The technology as it currently stands is best applied in reduced light — such as a shed or in the evening. Scanning dilated pupils of amenable cows can be completed in 1–3 minutes per cow. This is contingent on having the animal suitably restrained to allow the scanner to shine a light in their eye and collect the resultant images.

The trial site had a covered crush, but the cows only enter the covered section of the yard when entering the crush, being standing in the direct sunlight beforehand (see **Error! Reference source not found.**). At least five minutes of reduced light is necessary for the pupils to dilate sufficiently.

The cows' slit-like iris makes it difficult to position the iTRAK scanner to ensure the optic disc region and associated veins are captured in the scan (see Figure 6). There exists the possibility that two scans of the same retina may have minimal overlap of images, and this may have implications for accurate animal identification.

Operator comments include that the current scanner technology of an iPod connected to a scanner is difficult for the operator to view the scanner screen and manipulate the cows' head to take the scan. The automated picture capture technology (that takes a photo when sufficient retina is in the picture) is effective, but placement of the scanner to ensure the region surrounding the optic disc is captured requires experience. This may be improved by adjustments to the hardware to allow the operator to see the scan site whilst handling the cows head safely.

7. Future research and recommendations

Algorithm development requires large training and testing datasets and a process of algorithm refinement that focuses on accuracy and robustness (i.e. preventing overfitting). This will be achieved through collection of a data set obtained from field studies across multiple farms and operators. Noting that the greater the sample size and variability within it (as in age, sex, geography, etc.) will deliver greater assurance of accuracy and robustness, at least 1,000 cows providing multiple images obtained from a minimum of 5 farms across at least two visits is estimated. This will also be useful in terms of developing suitable operator training.

Further software development is also required to enable images to be rotated as part of the matching process with images in the reference library. This data conversion and standardisation is part of algorithm development, especially for biological data, but may require experts in image analysis to ensure retinal scans are standardised before classification.

Further software refinement is required in relation to preferred image selection. Presently, once images of the retina are captured, the operator selects the 'best' image. This creates an operator effect. Automation of this process will negate this issue.

The current version of the software was an initial version designed for the trial. It has limitations in terms of requiring internet connectivity and has not considered any user requirements. A complete software development plan is required to ensure whatever is developed is fit-for-purpose.

Improvements in hardware are required – to allow safer operation, to collect all the retina (scan along the transverse length of the cows' slit-like pupil), and to allow the operator to see where the camera has focused whilst safely engaging with the head of the animal.

Modifying camera/hardware to allow collection of suitable retinal images from animals exposed to ambient light seems intractable, without resorting to use of pupil-dilating treatments beforehand.

Further assessment is also required in relation to animal temperament and handling facilities. This would include assessing cattle from extensive environments that infrequently interact with humans and identify the types of handling facilities needed to minimise any WH&S risks.

8. Appendix

8.1 Photographs

Figure 5 Trial site crush and covered yard

Figure 6: Constricted (slit-like) pupil on cow examined on 15th April 2022 (day visit)

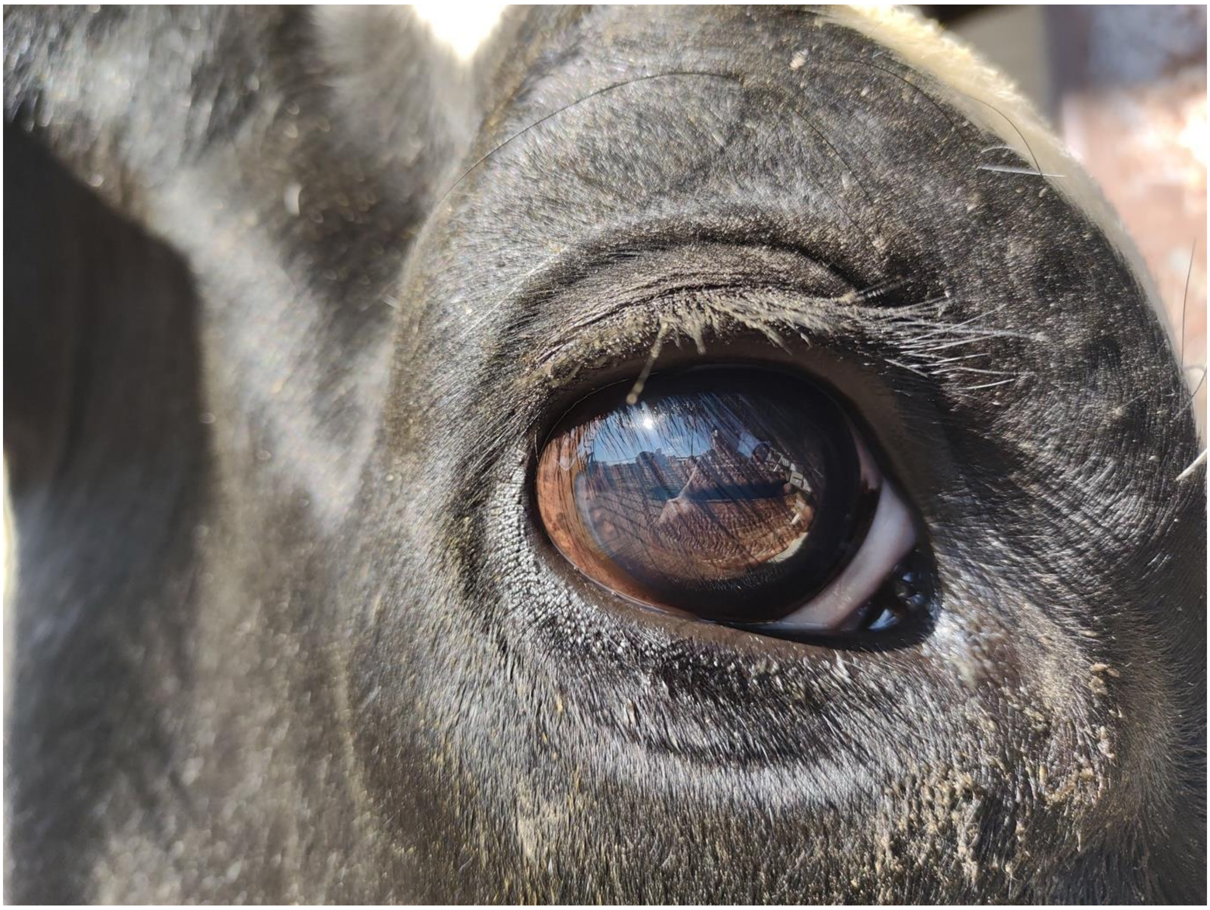


Figure 7 **Scanning cattle at night**

Figure 8 Scanning cattle at night

Figure 9 iTRAK Software Output